

Blood Flow Measurement using Self-Calibrated Spiral Sensitivity Encoding

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Abstract: Imaging of the blood flow is investigated using spiral phase contrast with self-calibrated sensitivity encoding reconstruction. Spiral sampling of k-space has good motion and flow properties and efficient k-space coverage. Using SENSE, one can reduce the acquisition time or increase the spatial resolution. Here, a self-calibrated sensitivity encoding reconstruction for spiral sampling is introduced for measuring the blood flow in vessels. Undersampling up-to rate 4 is studied which results in decreasing the image acquisition time and breath-hold duration significantly while keeping spatial and temporal resolution constant.

Method

A through plane spiral phase contrast sequence is developed by adding a bipolar gradient to measure the blood flow velocity through vessels. In order to minimize the echo time, the bipolar flow encoding gradient is combined with the slice refocusing gradient. Furthermore, first moment difference between two encoding steps without considering each individual bipolar first moment is used as the bipolar gradient design constraint [1]. An improved spectral-spatial pulse for suppression of fat signal is used for slice selection [2]. To minimize swirling artifacts, a two-way skip randomized interleaf ordering is used in all imaging experiment [3]. A conjugate-gradient SENSE reconstruction [4] is used with the speed up method described by Wajer [5] for image reconstruction. Coil sensitivity map acquisition is one of the crucial steps in the reconstruction process which generally requires an additional acquisition experiment with body and phase array coils. In order to achieve a self-calibrated reconstruction, even and odd spiral interleaves are acquired in alternative cardiac phases. A coil sensitivity map is constructed using temporal integration of the data in all cardiac phases to achieve a fully sampled k-space [6]. This low resolution map is reconstructed with a gridding procedure and used for the SENSE reconstruction.

Images were acquired on a GE Signa CV/i 1.5T MR imaging system (GE, Waukesha, WI) and an 8-channel cardiac phased array coil (Nova Medical, Wakefield, MA). Two low resolution single-shot images with different echo times were acquired at the end of the cardiac scan for off-resonance map calculation and correction using the linear field map for all cardiac phases [7].

Normal volunteers were imaged with informed consent as approved by the NHLBI IRB. Peripheral gating is used for all experiments. The spiral sequence consisted of 32 interleaves for a full acquisition, and for each undersampling rate this number reduced proportionally. This undersampling will keep the spatial and temporal resolution of the image the same while reducing the total image acquisition time. The field of view of 34cm was prescribed producing a nominal resolution of 1.7x1.7mm. A single interleave per segment was used to achieve temporal resolution of 25ms. An undersampling rate of {2, 3, 4} are used for acquisition of the through plane flow in ascending aorta. This undersampling reduces the breath-hold duration from 32 to {16, 10, 8}.

Result

An axial slice through aorta was selected for measuring through plane flow. A region of interest through ascending aorta was selected and flow rate was calculated through the cardiac cycle. Figure 1 showed the magnitude and phase contrast images reconstructed for fully sampled and different under-sampled reconstruction in the same cardiac phase. Figure 2 showed the aortic flow comparing different undersampling rates vs. fully sampled data.

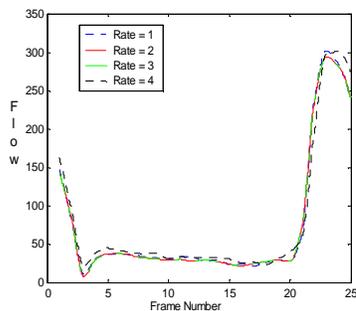


FIG 2 Blood flow (ml/s) in ascending aorta for different under-sampling rate

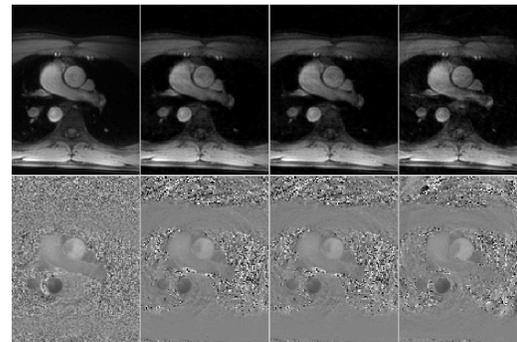


FIG 1 Magnitude and phase contrast images for under-sampling rate {1, 2, 3, 4 from left to right}

Discussion

An under-sampled spiral reconstruction was presented for blood flow measurement through ascending aorta. The measured blood flow showed an agreement between fully sampled and under-sampled reconstruction up-to rate 4. This undersampling scheme can drastically reduce the breath-hold duration, making it feasible to acquire a high spatial resolution blood flow imaging with short breath-hold on patients.

References

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